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Efficacy of burrow fumigation in reducing rodent activity in Philippine rice fields

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Abstract: The purpose of this study was to evaluate the effectiveness of rodent (*Rattus rattus mindanensis*) burrow fumigation in Philippine rice fields using gas cartridges. Criteria used for evaluation were rat-damaged tillers, a rat activity index, active burrow counts, and burrow occupancy. Only 26% of 303 total burrow systems and only 47% of 79 active burrow systems in two trials had rats. Rat activity was reduced only when burrow occupancy was highest. For the rodent species and cropping system studied, it appears that burrow fumigation with gas cartridges requires more input for the benefit received when compared with other available rodent control methods.

INTRODUCTION

Several methods are available for killing rodent pests in burrows, including using custom-made flame throwers, digging or flooding burrow, using dogs, and fumigating with toxic gases. Fumigation with calcium cyanide, aluminum phosphide, or sulfur is a popular technique used throughout South and Southeast Asia to control rats in rice and other tropical crops (Greaves *et al.*, 1975; Lal, 1975; Lam, 1975; Fall, 1977; Soekarna *et al.*, 1980). Elsewhere, methyl bromide, chloropicrin, carbon dioxide, and carbon monoxide have been used to fumigate burrows (Meehan, 1984). Fumigation has frequently been used in India after rodenticide baiting operations to reduce residual populations (Balasubramanyam *et al.*, 1985).

Usually fumigation "effectiveness" has been evaluated relative to the number of rats killed and not necessarily to protection of the crop at risk. However, one field study used rat-damaged tiller counts, crop yields, and a cost:return ratio to measure fumigation effectiveness (Greaves *et al.*, 1977). Other parameters used to measure efficacy included counting of active burrows before and after treatment (Shah, 1969; Srivastava, 1969; Durairaj and Guruprasad, 1975; Lam, 1975; Jackson, 1979; Byer, 1980; Savarie *et al.*, 1980), using a snap-trap index alone (Greaves *et al.*, 1977) or with active burrow counts (Chopra, 1984; Shankuntala and Durairaj, 1975), and using radiotelemetry (Fagerstone *et al.*, 1981; Matschke and Fagerstone, 1984). Salmon *et al.* (1982) combined active burrow counts with live animal counts to compare two fumigants against ground squirrels. Mead-Briggs and Trout (1975) assessed effectiveness by perforating mole tunnels before and after fumigation control and quantifying the number repaired.

Potential advantages of burrow fumigation treatments over other rodent control techniques include having (1) an immediate effect, (2) specificity to the target species (rodent pest) with limited secondary hazard to nontarget species, (3) little or no hazardous residues, (4) reduced preparation time (e.g., no bait mixing or prebaiting), (5) less dependence on rodent behaviour (e.g., attracting rats to bait holders), and (6) the potential to limit reporudction by disrupting breeding/nesting in burrows. Potential disadvantages include (1) burrows may not be visible or easily detected, (2) rodents may not be present in visible burrows, (3) rodents with complex burrow systems may plug or block burrow openings being fumigated, and (4) predators or other beneficial nontarget species present in treated burrows may be adversely affected.

The ideal fumigant would preferable (1) be a solid (vs. a gas or liquid) for ease of handling, application, storage, and transport (Gleeson and Maguire, 1957), (2) have a high vapor pressure for good dispersion, (3) have a low toxicity to man, but high toxicity to the target pest, (4) have a characteristic odor (or a warning irritant added) or visibility for easy detection, (5) not require special equipment, lengthy preparation, or excessive manpower, (6) be heavier than air, (7) be nonflammable, (8) be effective in all soil conditions, and (9) be inexpensive. No fumigant currently in use incorporates all of these charadteristics.

The Gas Cartridge®[1], a multi-ingredient fumigant that releases carbon monoxide and other toxic fumes when burned, was used against burrowing rodents for many years by the U.S. Fish and Wildlife Service and possesses many of the

[1]Reference to trade names does not imply U.S. Government endorsement.

favorable characteristics of an ideal fumigant. Savarie *et al.* (1980) developed a two-ingredient cartridge comprised of sodium nitrate and charcoal. Both laboratory (Elias *et al.*, 1983) and field tests (Elias *et al.*, 1980) of this simpler cartridge were effective on wild Norway rats *(Rattus norvegicus)*, where a 77% reduction in numbers of reopened Norway rat burrows was achieved after fumigating infested sites at a cattle feedlot. Such a cartridge may have application in developing countries where fertilizer and charcoal are available.

While burrow systems of many rodent species can be extensive in terms of total length and complexity, the burrow system of the Philippine ricefield rat (*Rattus rattus mindanensis* Mearns) is relatively simple. Burrow length averages about 1-2 m, and there are usually only two (sometimes three) openings—one, obvious; the other(s) plugged, concealed with vegetation and used for escape. Most burrows in rice paddies are found in dikes above the water line; hance, wider and more abundant dikes offer more burrowing space. Field studies of the Philippine ricefield rat and the Asian ricefield rat (*Rattus argentiventer*), a similar species present in the Philippines, have indicated that a high percentage of pregnant females inhabit burrows (de Jesus *et al.*, 1960; Sumangil, 1971). Burrows are the preferred nesting site when burrowing space is available. However, when habitats are flooded, above ground nests are readily used.

The purpose of our investigation was to evaluate the effectiveness in Philippine rice fields of fumigating using Gas CartridgesR. Possible adverse affects on nontarget species were noted. Criteria used for evaluation were rat-damaged tillers, rat activity indexes, active burrow counts, and mortality of rats and other vertabrates in burrows.

METHODS

Two separate field trials were completed at the International Rice Research Institute (IRRI) in Los Banos, Philippines. Trial No. 1 was conducted from February to May 1981, and Trial No. 2 was conducted in January 1983. All rice in treated plots was transplanted.

Trial No. 1

In the IRRI upland area, two irrigated plots containing mixed rice varieties (Plot A, 4.0 ha, and Plot B, 2.95 ha) were used. Plots A and B were nearly adjacent, separated only by an access road; each plot was enclosed by a fenced barrier designed to limit rat immigration.

At each of three rice growth stages — vegetative [44 days after transplanting (DAT)], flowering (66 DAT), and mature (93 DAT)—all visible rat burrow openings within each plot were marked with bamboo sticks, plugged with mud, and examined the following morning. Active burrow openings (those reopened or newly made) were then fumigated once at each growth stage by inserting one lighted 85-g (8.9-cm fuse), U.S. Fish and Wildlife Service, cylinder-shaped (3.8 x 8.9 cm) Fas CartridgeR (EPA Reg. No. 6704-4)[1] this cartridge contained 10.84% sulphur, 17.34% charcoal, 3.25% red phosphorus, 14.09% mineral oil, 43.36% sodium nitrate, 3.52% sawdust, and 7.60% inert ingredients. The entrance hole was then plugged along with any exit hole emitting smoke, which defined a particular active burrown system. Two hours later, all burrow systems in the vegetative rice growth stage were opened and examined. Due to time and labor constraints, 20% of the burrow systems in the flowering and reproductive rice growth stages was randomly selected and examined. Species, age, and sex of dead rats were recorded. Results from the flowering and mature growth stages were then extrapolated.

Rat activity was determined by using a tracking tile index (West *et al.*, 1976). At each site, 56 white vinyl plastic floor tiles (15.2 x 1.52 cm) with one-half the upper surface lightly coated with mineograph ink were placed 15 m apart on or near the dikes for 3 consecutive nights before and after treatment. Tracking tile with one or more rat footprints on the uninked portion were recorded as positive. The uninked portion was then cleaned with cotton batting and acetone, the inked portion reinked (if needed), and the prepared tiles set out again in late afternoon.

Trial No. 2

The second field trial was conducted in the IRRI lowland area. Six irrigated rice plots, averaging 2,179 (1,320-2,940) m^2, were selected; two plots were used for each of the three growth stages described in Trial No. 1. Dike length averaged 230 (199-266) m. These plots were separated by at least 100 m of rice fields. Fumigation techniques and rat activity measurement procedures were followed as described for Trial No. 1. Nine to 16 tracking tiles were used in each plot, depending on plot size, and all fumigated burrow systems were dug up. Within 1 week after fumigation, all visible burrow openings were marked with bamboo sticks, closed with dirt, and checked the next morning; all reopened and newly excavated burrows were recorded.

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[1]This product is now registered with USDA by EPA (Reg. No. 56228-2).

To evaluate quality assurance of the Gas Cartridge®, its shelf life was tested over a 2-year period by periodically test-firing one randomly selected cartridge from the original shipping box or later from an unselaed plastic bag. Cartridges were received from the United States in March 1981 and subjected to ambient indoor storage conditions, mostly warm and humid, in two locations: Los Banos, Laguna Province, and Banaue, Ifugao Province. Individual cartridges were removed from storage and burned above ground in low wind (≤4 mph) every 2-3 months; observations on burn time (duration of flame), flame (not visible, visible, very visible), and smoke (light, medium, heavy) were noted.

RESULTS

About 74% of the burrow systems in all treated plots from both trials had no rats present during fumigation (Table 1). About half (55%) of all burrow openings were active or reopened after closure, and only 35% of these active openings contained rats. Reduction of rat activity after fumigation was directly related (r = 0.79) to burrow occupancy; the higher the occupancy rate, the greater the reduction in activity (Fig. 1). However, rat activity was never reduced more than 57%.

Table 1. The presence, characteristics and use of rodent burrows in two fumigation trials in experimental rice fields at the International Rice Research Institute, Los Banos, Philippines, during 1981 and 1983.

Trial No.	Total visible burrow openings	No. (%) active[a] burrow: Openings	Systems[b]	Systems with rats	Estimated % of total burrow systems without rat (S)[c]
1	210	128 (61)	84	38 (45)	73
2	196	97 (49)	83	41 (49)	75
Total (mean)	406	225 (55)	167	79 (47)	74

[a] = Determined by marking and plugging all visible openings and examining the study area the following morning for reopened or newly formed burrow openings.

[b] = Continuous tunnel (s) connecting one or more openings determined during fumigation by smoke escaping through exit holes.

[c] = Calculated by: (1) dividing 210 and 196 (total visible burrow openings in Trial Nos. 1 and 2, respectively) by 1.5 and 1.2 (active burrow openings/system in Trial Nos. 1 and 2, respectively); then, (2) dividing the number of systems with a rat (38 and 41, respectively) by the result from Step 1 and multiplying by 100 to obtain a percent; and, (3) subtracting this percent from 100.

For example: (1) 210 ÷ 1.5 = 140
(2)38 ÷ 140 = 0.27 x 100 = 27%
(3)100 - 27% = 73%

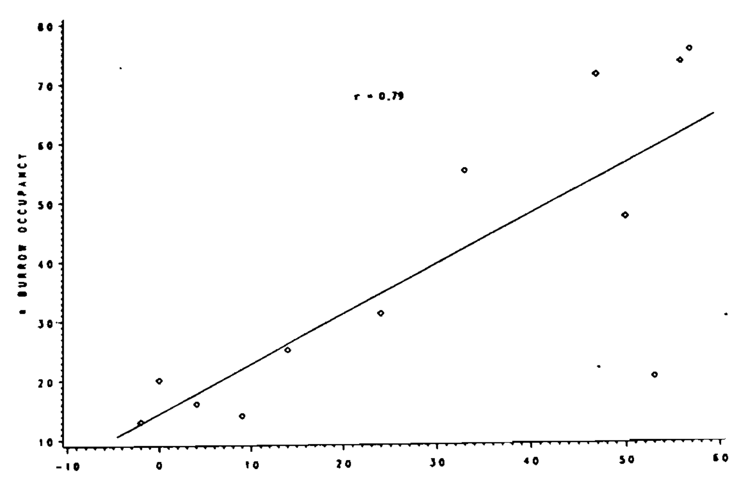

Figure 1. The relationship of burrow occupancy (% active burrow openings with one or more rats) to reduction of rat activity following burrow fumigation treatments in two trials.

Trial No. 1

A total of 210 burrow openings in dikes (3.8 openinds/100m) was observed in both plots—57 at the vegetative, 66 at the flowering, and 87 at the mature crop stage (Table 2). The number of active burrow openings was only 128, which included 31 at the vegetative, 35 at the flowering, and 62 at the mature crop stage. Of these 128 active burrow openings, 71 were reopened following plugging and 57 were new. The 128 active burrow openings represented 84 burrow systems (determined by smoke emission during fumigation) or an average of 1.5 openings observed per burrow system. Of the 84 active burrow systems gassed, 38 (23 in the vegetative stage) contained a rat. No more than one rat was recovered from any one fumigated burrow system. Males were recovered only from plots in the vegetative stage; 87% of all recovered rats were female.

About 21% of the fumigated burrow systems contained dead toad (*Bufo marinus*). Toads were never found in burrows with a rat or another toad. Toad occupancy did not vary much from one crop stage to another.

Table 2. Efficacy of Gas Cartridges® used in *Rattus mindanensis* burrows in two study plots at three growth stages of upland, dry season, irrigated rice at the International Rice Research Institute during February-May 1981.

Crop growth stage	Total burrow openings (density)	No. active burrow openings	No. active burrow systems			
			Treated[a]	With a rat	With a toad	Empty
Vegetative (44 DAT)[b]	57 (3.1/100 m)	31	31	23	6	2
Flowering (66 DAT)	66 (3.6/100 m)	35	22	10.5[c]	5.8[c]	5.8[c]
Maturity (93 DAT)	87 (4.7/100 m)	62	31	4.8[d]	5.8[d]	20.5[d]
TOTAL	210 (3.8/100 m)	128	84	38.3	17.6	28.3

a Some active burrow openings were part of the same burrow system.
b DAT = Days after transplanting.
c Estimate based on four random burrows dug up.
d Estimate based on six random burrows dug up.

The rat occupancy pf active burrow openings during treatment declined from a high (74%) in the vegetative stage to a low (8%) in the mature crop stage (Table 3). The percent reduction in rat activity after treatment also declined from 57% in the vegetative rice to 1% in the mature rice. Rat activity was reduced 28% for all crop stages. Based on 400 randomly sampled hills in each plot, the mean percent rat-cut tillers at three rice growth stages was 0.0 (vegetative), 0.5 (flowering), and 2.8 (Mature).

Table 3. Effect of a single rat burrow fumingation treatment on rat activity at different growth stages of upland, dry season, irrigated rice at the International Rice Research Institute during February-May 1981.

Crop growth stage	Mean burrow occupancy[b] (n=2)	Rat activity[a]		
		Before	After	% reduction
Vegetative (44 DAT)[c]	74	108	47	57
Flowering (66 DAT)	30	54	44	19
Mature (93 DAT)	8	94	93	1
Total (mean)	30	256	184	28

[a] Number of positive tracking tiles from 112 tiles/night/two sites for 3 consecutive nights.
[b] The % of active burrow openings with one or more rats of any size.
[c] DAT = Days after transplanting.

Trial No. 2

In the second, or lowland trial, 196 burrow openings were counted along 1,378 m of dike, an average of 14 openings per 100 m (Table 4). Burrow density was greater in the flowering and mature growth stages (23 and 15 per 100 m) than in the vegetative stage (5 per 100 m). About half (97) the burrow openings at each growth stage were active (reopened or newly made). The 97 active openings represented 83 burrow systmes (about 1.2 openings per burrow system).

Of the 83 systems fumigated, 40 were empty and 41 contained dead or dying rats, including 19 adults (68% females) weighing 100 g or more, and 110 young weighing less than 100 g (most were less than 25 g). The majority of adult rats were killed in the flowering growth stage (0.3 per active burrow system), and the majority of nestling and young rats (<100 g) were killed in mature rice (2.0 per active burrow system). Only two systems contained a dead toad (*Bufo marinus*).

Table 4. Efficacy of Gas Cartridges® used in *Rattus mindanensis* burrows in two study plots at each of three growth stages of lowland, irrigated rice at the International Rice Research Institute during January 1983.

Crop growth stage	Total burrow openings (density)	No. active burrow openings	No. active burrow systems			
			Treated[a]	With a rat	With a toad	Empty
Vegetative (44 DAT)	24 (5/100 m)	12	11	2	2	7
Flowering (66 DAT)	107 (23/100 m)	54	46	21	0	25
Maturity (93 DAT)	65 (15/100 m)	31	26	18	0	8
TOTAL	196 (14/100 m)	97	83	41	2	40

a Some systems contained more than one opening.

The active burrow opening occupancy rate increased with the age of the rice crop, from a low of 17% in vegetative rice to a high of 58% in mature rice (Table 5). Overall rat activity was reduce after treatment by 35% and active burrows by 46%, with the greatest effect taking place during the flowering (45 and 56%, respectively) and mature (49 and 32%, respectively) growth stages.

Table 5. Effect of a single rat burrow fumigation treatment on rat activity and burrowing in six plots, two for each of three different lowland, irrigated rice growth stages at the International Rice Research Institute during January 1983.

Crop growth stage	Mean burrow occupancy[b]	Rat activity[a]			% reduction of active burrow openings
		Before	After	% reduction	
Vegetative (44 DAT)[c]	17	42	40	5	42
Flowering (66 DAT)	39	60	33	45	56
Mature (93 DAT)	58	49	25	49	32
Total (mean)	42	151	98	35	46

[a] Number of positive tracking tiles from 32 (vegetative), 27 (flowering, and 21 (mature) tiles/night/two sites for 3 consecutive nights.
[b] The % of active burrow openings with one or more rats of any size.
[c] DAT = Days after transplanting.

The shelf life tests indicated that high humidity was not detrimental to stored cartridges (Table 6). Burn time remained between 100 and 125 seconds after a shorter burn time (45 and 60 seconds) in the first two tests. The smoke produced remained "medium", and the flame was usually "very visible" throughout the testing period. Ignition of the fuse remained consistently good, and complete combustion of the cartridge occurred throughout the testing period, usually within 150 second. Cartridges placed in burrow burned well (very few unburned components remained) in all tests during the 2-year period.

Table 6. Burning characteristics of Gas Catridges® stored in tropical conditions from march 1981 to April 1983.

Date	Burn time[a] s	Smoke[b]	Flame[c]	Complete combustion[d] s
20 Oct 1981	45	2	3	–
11 Mar 1982	60	2	3	600
18 Jun 1982	125	1.5	3	–
1 Aug 1982	100	2	2.5	135
3 Sep 1982	120	2.5	3	–
6 Oct 1982	120	2	2.5	120
16 Nov 1982	120	2	2.5	120
10 Jan 1983	105	2	3	150
5 Apr 1983	105	2	3	–

[a] Presence of visible flame in seconds.
[b] 1 = light; 2 = medium; 3 = heavy.
[c] 1 = not visible; 2 = visible; 3 = very visible.
[d] Time is seconds (s) until complete ash formation without flame or smoke.

DISCUSSION

In many burrow fumigation operations, no differentiation of active or inactive openings is made and all rat burrow openings (or systems) are treated. Had we fumigated all burrow systems (active and inactive), about 74% of the effort would have been nonproductive since only 26% of the estimated total burrow systems in this study contained a rat (Table 1). Even when only active burrow systems are fumigated, most of the effort might be nonproductive if no rats are present (53% of active burrow systems in our field trials were empty). Other burrow treatments like flame throwers and digging might probably produce similar, or even worse, results.

The primary reason for this lack of efficacy is that the Philippine ricefield rat is not highly fossorial. Except when needing temporary shelter (males or females) and when nesting (females), it apparently remians above ground in vegetation that provides adequate shelter. Field observations in Cotabato, Mindanao, including radiotracking of 11 *R. argentiventer*, indicated that rats were frequently resting and nesting outside of burrow (Rodent Research Center, 1971). When Tucay (1979) collected all rats (both *R. argentiventer* and *R. r. mindanensis*) from 25 1-ha rice fields at harvest time, 48% came from burrows; the rest were above ground.

In Malaysia, Lam (1975) excavated 416 active *R. argentiventer* burrows and found that only 23% contained rats. Eighty-six of these 416 active burrow remained active after three consecutive daily treatments with calcium cyanide; about one-half (47%) contained rats. The percent of total burrow openings we found to be active (55%) was simlar to what Lam (1975) found (59%).

We were able to reduce rat activity by fumigation but only when the occupancy rate of burrows was above 30% (Figure 1). Rats that were killed by fumigation were apparently responsible for 28% (Table 3) of the rat activity in Trial No. 1 and 35% (Table 5) in Trial No. 2. The moderate reduction in rat activity and active burrows after treatments was below that achieved using other rat control methods (Ahmed, 1981).

The fact that active burrow openings in Trial No. 2 were reduced only 46% (Table 5) indicates that additional resident or imigrant females burrowed for nesting purposes almost immediately (within days) after the fumigation treatment. Many nonburrowing rats were probably present in and around the study plots during fumigation. When rice fields are attractive, immigration of rats would be expected to take place relatively quickly (West *et al.*, 1976). However, baiting with rodenticides would limit this immigration (West *et al.*, 1975; Fall, 1977), and negate the need for fumigation or other burrow treatment.

Burrow occupancy declined in Trial No. 1 from a peak in February during the vegetative rice growth stage to a low in April (late dry season) during the mature stage. Given a choice of three rice growth stages, we would expect a ricefield rat to be more attracted to the mature stage that provides more shelter and a higher quality food source. Female rats usually respond to these favorable conditions by breeding, burrowing, and nesting (Uhler, 1967; Rodent Research Center, 1971; Marges, 1972; Fall, 1977). However, Trial No. 1 was upland and conducted well into the dry season, a time when rat populations are usually stressed from a lack of food, water and shelter. With less breeding occuring in April due to unfavorable conditions, fewer female rats would be burrowing for nesting purposes. This would explain the low burrow occupancy in the mature crop stage in Trial No. 1. Trial No. 2 was lowland and conducted at the beginning of the dry season, a time when rat populations were not yet stressed.

Burrow treatment prior to natural mortality and decreased breeding (and hence decreased burrowing by females) during the dry season would not be beneficial. Although irrigated areas reduce the stress to rats during the dry season, decreased breeding still occurs. In the dry season, ricefield rats tend to congregated in remaining habitats which offer shelter, but few occupy burrows; they prefer above ground vegetation for concealment. An extreme example of this phenomena was documented by Libay and Fall (1976); 2,875 adult rats from 10 areas, totaling 2,875 m^2, were collected above ground in marsh vegetation adjacent to harvested rice fields.

The long-term effect of burrow treatments on the reproductive potential of the treated rat population is unknown. However, the elimination of cyanide fumigation of burrows at the IRRI in 1979 did not lead to substantial rat population increases or increased damage to rice over a 3-year period (Ahmed, 1981; Santos, 1983).

Tiller damage by rats was measured in Trial No. 1, but was not dramatically reduced when compared with other rat control methods used or tested at the IRRI (Ahmed, 1981).

The cost of treatment was probably high compared with other rodent pest management techniques available (Ahmed, 1981). The cartridge used was commercially available for about U.S. $0.20, including shipping. It took 2 hours to treat 4 ha with 19-23 active burrow systems and about 1 hour to treat 3 ha with 3-11 active burrow systems. Manpower and time would raise the total investment of burrow treatment considerable and should be carefully evaluated before any large-scale use or recommendation is followed. A smaller cartridge, more suitable for the shorter *R. r. mindanensis* burrows, could be manufactured locally with only two ingredients (Savarie *et al.*, 1980) at a much lower cost.

The shelf life of the cartridges appears to be very good since the cartridges were not adversely affected by warm, humid conditions over a 2-year period.

The only nontarget species found in fumigated burrows was *Bufo marinus*. Although this toad is potentially beneficial (National Academy of Sciences, 1970; Castro *et al.*, 1985), populations would probably not be affected by fumigation treatments. Only 20 toads were found in 167 burrow systems with most (18 toads in 84 systems) found in the upland site in Trial No. 1. Neither *lizards*, as reported by Villidolid (1956), nor frogs, which were locally present, were found in treated burrows.

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REFERENCES

AHMED, M.S. (1981) Evaluation of rat control techniques in experimental fields of the International Rice Research Institute. *Unpublished M.S. Thesis*, University of the Philippines at Los Banos. 62 pp.

BALASUBRAMANYAM, M., CHRISTOPHER, M. J. and PURUSHOTHAM, K.R. (1985) Field evaluation of three anticoagulant rodenticides against rodent pests in paddy fields. *Tropical Pest Management* 31(4): 299-301.

BYERS, R.W. (1980) Evaluation methods for fumigant control of eastern woodchucks. *Pest Control* Sept.: 24, 26, 61.

CASTRO, F.B., RELOBA, R.G., and GARCIA, A.S. (1985) Notes on *Bufo marinus* Linn. as a potential predator to the oriental migratory locust. *Plant Protection News* (Philippines) 14(3-4): 15-18.

CHOPRA, G. (1984) Field efficacy of aluminum phosphide against rodents. *Indian Journal of Agricultural Sciences* 54(3): 204-205.

DE JESUS, Z., NEMENZO, F., SNATOS, J.V., SUMANGIL, J.P., and ROSELL, N.C. (1960) Studies on field rat infestations for biological control. *Natural and Applied Science Bulletin* 14(2): 129-186 (University of the Philippines).

DURAIRAJ, G. and GURUPRASAD, B.K. (1975) Evaluation of rodenticides in the paddy fields at Nagenahally (Mysore District). *All India Rodent Seminar*, Ahmedabad, September 23-26, 1975, Rodent Control Project, Sidhpur, pp. 258-264.

ELIAS, D.J., SAVARIE, P. J. and HAYES, D.J. (1980) Rat control at a cattle feedlot with fumigant cartridges. *Technical Report No. 1.*, Section of Supporting Sciences, Denver Wildlfe Research Center, Denver Colorado, 4 pp. (mimeo).

ELIAS, D.J. SAVARIW, P. J., HAYES, D. J., and FALL, M.W. (1983) A simulated burrow system for laboratory evaluation of vertebrate control fumigants. *In Vertebrate Pest Control and Management Materials:* Fourth Symposium, ASTM STP 817 (ed. D. E. Kaukeinen) pp. 226-230. American Society for Testing and Materials, Philadelphia, Pennsylvania.

FAGERSTONE, K. MATSCHKE, G., and EllAS, D. (1981) Radiotelemetry to evaluate effectiveness of a new fumigant cartridge for controlling ground squirrels. *Proceedings of the International Conference on Wildlife Biotelemetry in Laramie, Wyoming* 1981, 3: 20-25.

FALL, M.W. (1977) Rodents in Tropical Rice. *Technical Bulletin No. 36.* University of the Philippines at Los Banos, 37 pp.

GLEESON, J.P. and MAGUIRE, F.S. (1957) A toxicity study of rabbit fumigants. *Commonwealth Scientific and Industrial Research Organization (CSIRO) Wildlife research (Australia)* 2(2): 71-77.

GREAVES, J. H., CHOUDRY, M.A. and KHAN, A.A. (1977) Pilot rodent control studies in rice fields in Sind, using five rodenticides. *Agro-Ecosystems* 3: 119-130.

GREAVES, J.H., FULK, G.W. and KAHN, A. (1975) Preliminary investigations of the rice-rat problem in Lower Sind. *All India Rodent Seminar, Ahmedabad,* September 23-26, 1975, Rodent Control Project, Sidhpur, pp. 24-28.

JACKSON, W.B. (1979) Use of burrows for evaluating rodenticide efficacy in urban areas. *In Vertebrate Pest Control and Management Materials,* ASTM STP 680)ed. J. R. Beck) pp. 5-10. American Society for Testing and Materials, Philadelphia Pennsylvania.

LAL, S.S. (1975) Rodent control in agriculture: an integrated approach. *All India Rodent Seminar, Ahmedabad,* September 23-26, 1975, Rodent Control Project, Sidhpur, pp. 162-169.

LAM, Y.M. (1975) Evaluation of calcium cyanide for the control of padi field rats. *MARDI Research Bulletin* 3(2): 25-29.

LIBAY, J.L. and FA.., M.W. (1976) Observations on an exceptionally dense population of wild rats in marshland. *Kalikasan, Philippine Journal of Biology,* 5: 207-212.

MARGES, B.E. (1972) Reproduction and seasonal abundance of the ricefield rat (*Rattus rattus mindanensis* Mearns) in Siniloan, Laguan. *Unpublished M.S. Thesis,* University of the Philippines at Los Banos, Laguna, 43 pp.

MATSCHKE, G. H. and FAGERSTONE, K.A. (1984) Efficacy of a two-ingredient fumigant on Richardson's ground squirrels. *Proceedings of the Vertabrate Pest Conference in Sacramento, California* 1984, 11: 17-19.

MEAD-BRIGGS, A.R. and TROUT, R.C. (1975) A field evaluation of the effectiveness of a phosphine fumigant for mole control, *Agro-Ecosystems* 2: 1-13.

MEEHAN, A.P. (1984) *Rats and Mice: Their Biology and Control.* Rentokil Limited, W. Sussex, England, 338 pp.

NATIONAL ACADEMY OF SCIENCES. (1970) Principles of Plant and Animal Pest Control. Volume 5, *Vertebrate Pests: Problems and Control.* National Academy of Sciences, Washington, DC, 153 pp.

RODENT RESEARCH CENTER. (1971) *Unpublished Annual Report.* University of the Philippines at Los Banos, College, Laguna, 80 pp. (mimeo).

SALMON, T.P., GORENZEL, W.P. and BENTLEY, W.J. (1982) Aluminum phosphide (Phostoxin) as a burrow fumigant for ground squirrel control. *Proceedings of the Vertebrate Pest Conference in Monterey, California* (ed. R.E. Marsh), 10: 143-146.

SANTOS, O. (1983) Personal communication. Head, Farm Deprtment, International Rice Research Institute, Los Banos, Philippines.

SAVARIE, P. J., TIGNER, J. R., ELIAS, D.J., and HAYES, D.J. (1980) Development of a simple two-ingredient pyrothechnic fumigant. *Proceedings of the Vertebrate Pest Conference in Fresno, California* 1980, 9: 215-221.

SHAH, V.R. (1969) Some trials with aluminum phosphide (Celphos) for fumigation of burrows of rodents and crabs. *Bulletin of Grain Technology* 7(3): 166-167.

SHAHKUNTALA, N. and DURAIRAJ, G. (1975) Rodenticidal action on the population cycle of rodents in paddy fields. *All India Rodent Seminar, Ahmedabad,* September 23-26, 1975, Rodent Control Project, Sidhpur, pp. 129-132.

SOEKARNA, D., PARTOATMODJO, S., WIRJOSUHARDJO, S. and BOEADI. (1980) Problems and management of small mammals in Indonesia with special reference to rats. *In Proceedings of the Symposium on Small Mammals: Problems and Control* (ed. F.F. Sanchez), pp. 35-54. University of the Philipphines at Los Banos, December 6-8, 1977. Biotropica Spec. Pub. 12.

SRIVASTAVE, A.S. (1969) Evolution, development and standardization of technique for the eradication of field rats. *Indian Rodent Symposium,* Calcutta, December 8-11, 1966, John Hopkins University and Usaid, pp. 283-290.

SUMANGIL, J.P. (1971) Burrows and breeding of ricefield rats in Cotabato, Philippines. *Unpublished M.S. Thesis, Colorado State* University at Fort Collins, Colorado, 38 pp.

TUCAY, R.A. (1979) The relation of tracking tile index to actual population count of *Rattus argentiventer* Robinson and Kloss in Mindanao, Philippines, *Unpublished Thesis,* University of the Philippines at Los Banos, 34 pp.

UHLER, L.D. (1967) The reproduction of *Rattus rattus mindanesis* at the International Rice Research Institute, College, Laguna, Philippines. Philippines. *Philippine Agriculturist* 51(7): 576-580.

VILLIDOLID, D.V. (1956) A study of Cotabato rats and their control. *Areneta Journal of Agriculture (Philippines)* 3(2): 1-45.

WEST, R. R., FALL, M.W., and BENIGNO, E.A. (1976) Comparison of snap traps and tracking tiles for obtaining population indices of *Rattus rattus mindanensi* in the Philippines. *Philippine Agriculturist* 59(9&10): 379-386.

WEST, R. R., FALL, M.W. and LIBAY, J.L. (1975) Reducing interactions among rats to improve bait acceptance. *Philippine Agriculturist* 59(1&2): 31-36.